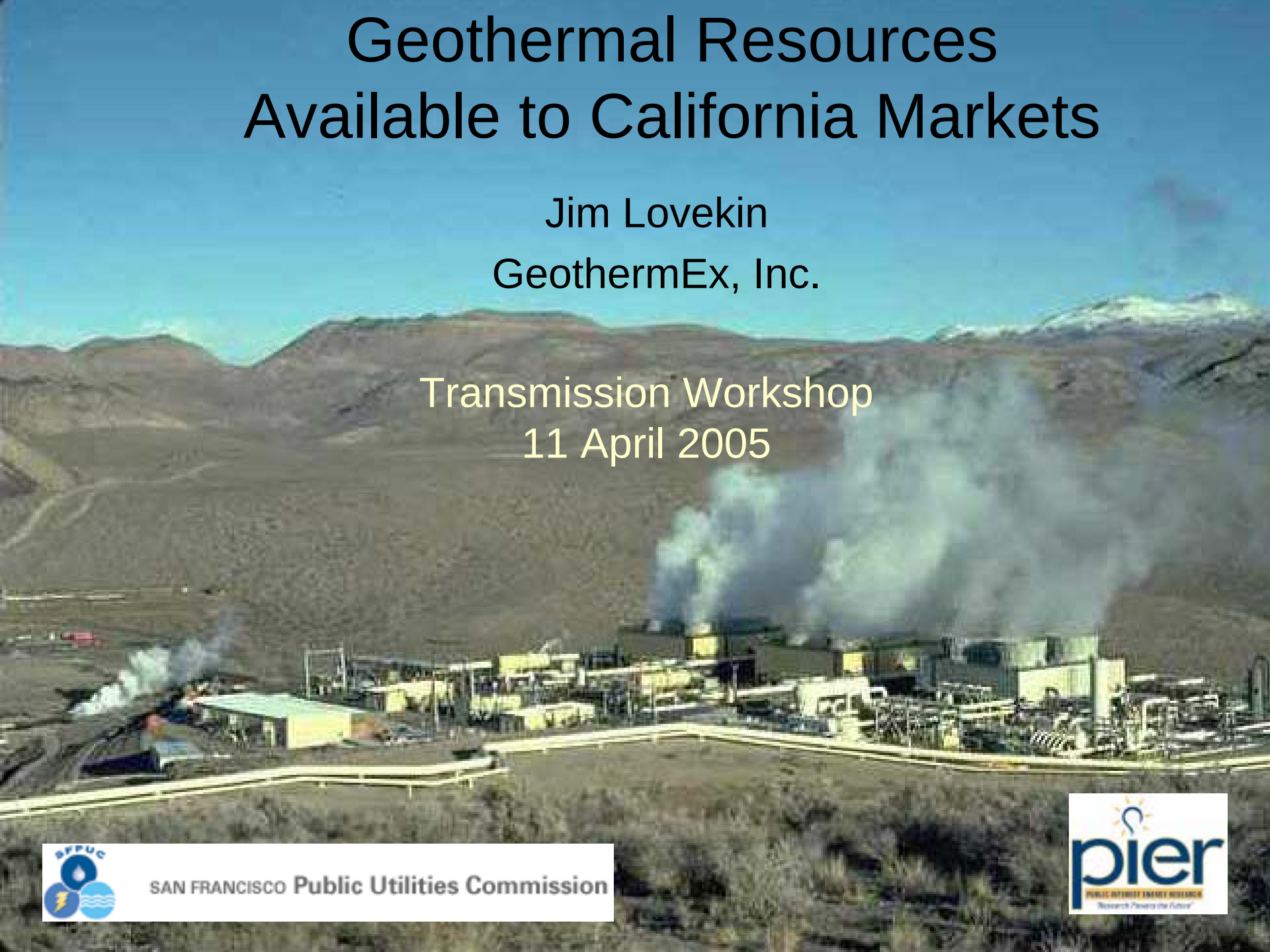
Geothermal Resources Available to California Markets

Jim Lovekin

GeothermEx, Inc.

Transmission Workshop
11 April 2005



SAN FRANCISCO Public Utilities Commission

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INTRODUCTION

- Summary of PIER-funded study
- Title: New Geothermal Site Identification and Qualification
- Part of : Hetch Hetchy / SFPUC Programmatic Renewable Energy Project
- Principal Authors: Chris Klein
  Jim Lovekin
  Subir Sanyal
- Project Coordination: Ray Dracker, CRS
- Project Manager: Valentino Tiangco, CEC

CHRONOLOGY

- Contract with SFPUC – October 2002
- Report submitted to CEC – April 2004
- Companion study of existing facilities
  - Currently in progress
  - Scheduled for completion by mid-2005

SCOPE OF WORK

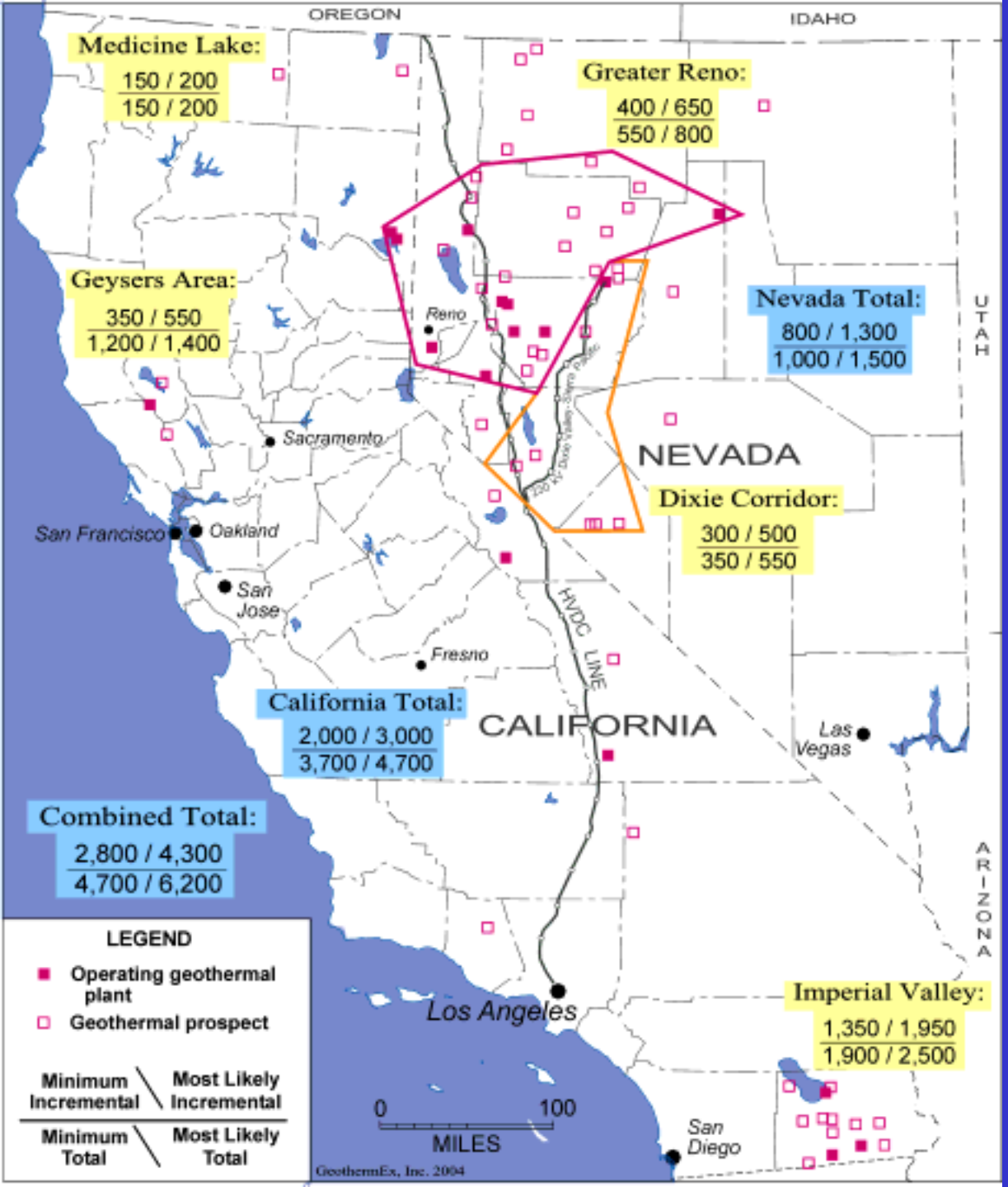
- Two main components:
  - Geothermal reserves
  - Estimates of capital costs

PROJECT MATURITY

- Challenge has been to objectively assess and compare resources at different stages of development

EXPLORATION – DEVELOPMENT CATEGORIES

A. Existing power plant is operating
B. No operating plant, but at least 1 well with tested capacity of 1 MW or more
C. No well tested at 1 MW or more, but downhole temperature of at least 212°F
D. Not meeting A, B, or C: resource properties from other sources (geology, geochemistry, geophysics)



Generation Capacities of Major Geothermal Resource Areas in California and Nevada (Gross MW)

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CALCULATION OF RESERVES

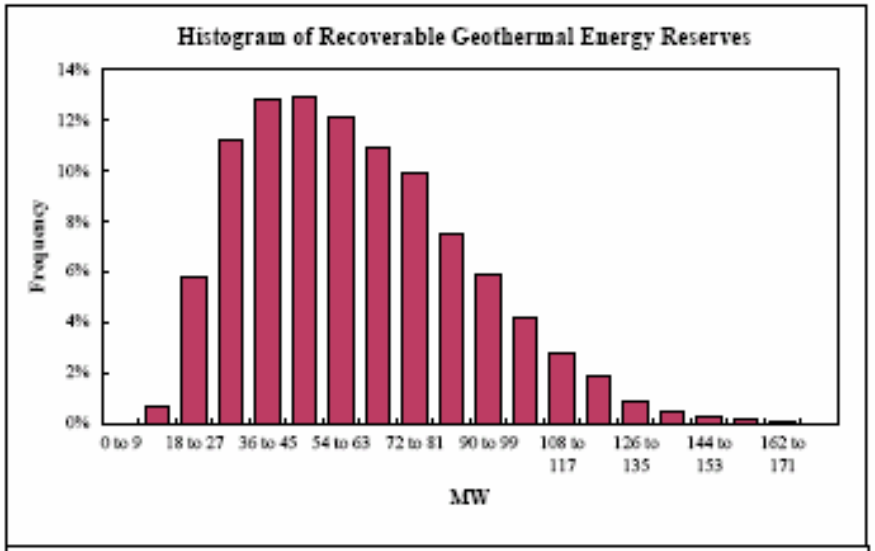
SUMMARY OF INPUT PARAMETERS

Variable Parameters	Minimum	Most Likely	Maximum
Reservoir Area (sq. mi.)	1.7	3.4	5.1
Reservoir Thickness (ft)	2500	3500	4500
Rock Porosity	0.03		0.07
Reservoir Temperature (°F)	340		380
Recovery Factor	0.05		0.20

Fixed Parameters		
Rock Volumetric Heat Capacity	39.0	BTU/cu. ft°F
Rejection Temperature	50	°F
Utilization Factor	0.45	
Plant Capacity Factor	0.90	
Power Plant Life	30	years

RESULTS

Statistics	MW	MW/sq. mi.	Recovery Efficiency
Mean	62.40	18.39	1.23%
Std. Deviation	26.82	6.84	0.43%
Minimum (90% prob.)	30.14	9.43	0.64%
Most-likely (Modal)	46.95	12.90	0.83%



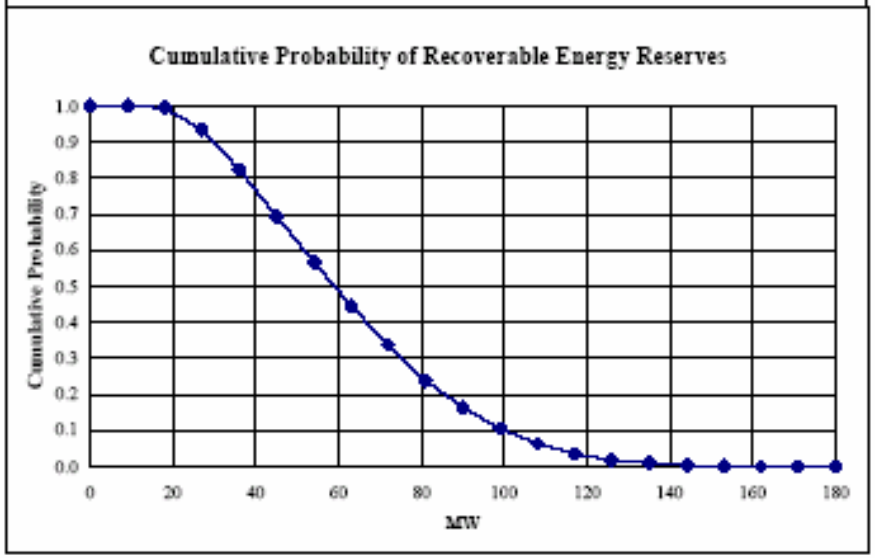


Figure FIS00-2:
Probabilistic Calculation of Geothermal Energy Reserves
FISH LAKE VALLEY, NEVADA

GENERATION CAPACITIES

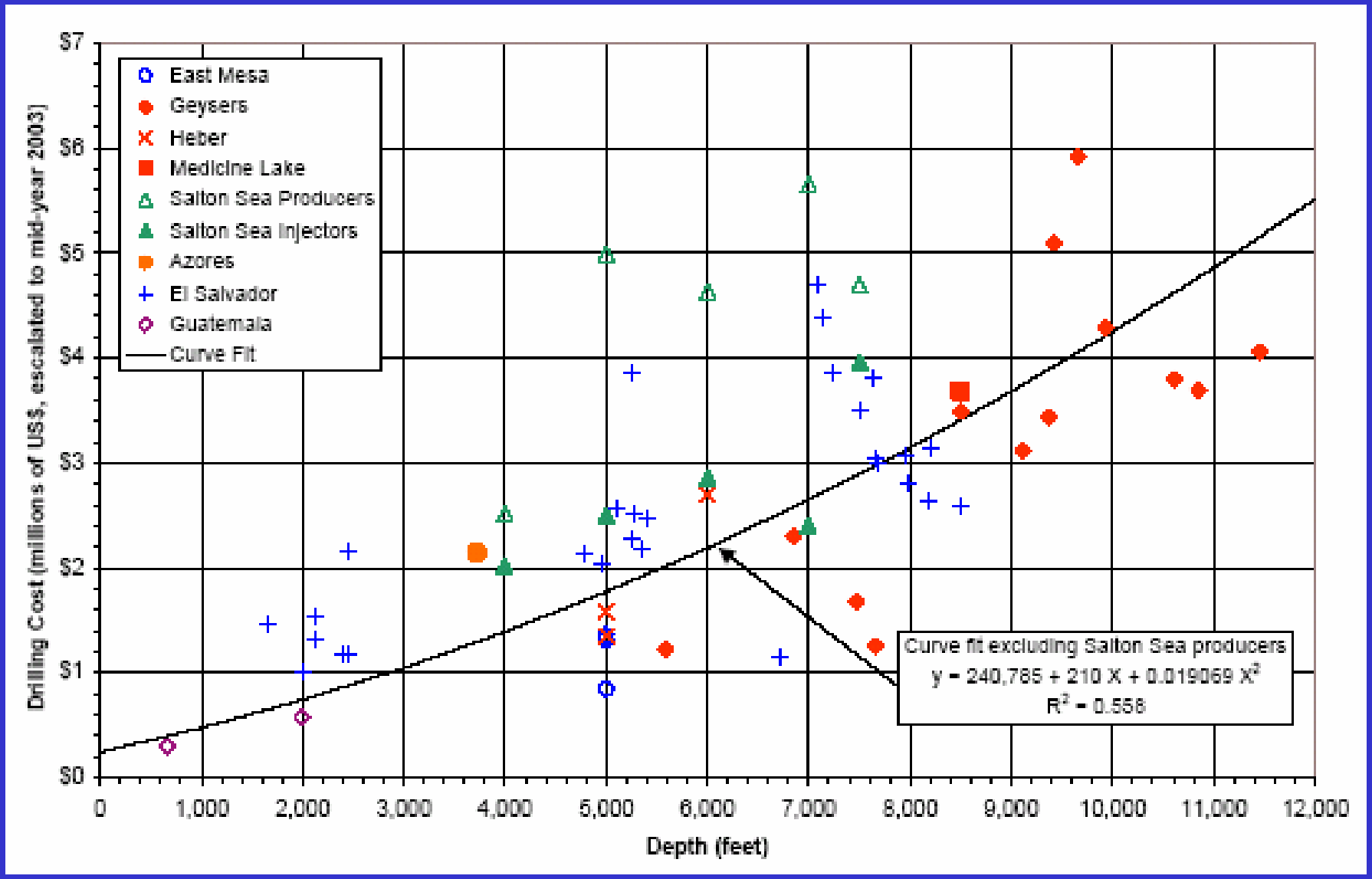
Area	Total Capacity Minimum (Gross MW)	Total Capacity Most-likely (Gross MW)	Capacity In Use (Gross MW)	Incremental Capacity Minimum (Gross MW)	Incremental Capacity Most-likely (Gross MW)	Most-likely Incremental As % of State Total	Most-likely Incremental As % of Grand Total
California							
Imperial Valley	1,900	2,500	550	1,350	1,950	65%	45%
The Geysers	1,200	1,400	850	350	550	18%	13%
Medicine Lake	150	200	0	150	200	7%	5%
Other	450	600	300	150	300	10%	7%
California Total	**3,700**	**4,700**	**1,700**	**2,000**	**3,000**	**100%**	**70%**
Nevada							
Greater Reno	550	800	150	400	650	50%	15%
Dixie Corridor	350	550	50	300	500	38%	12%
Other	100	150	0	100	150	12%	3%
Nevada Total	**1,000**	**1,500**	**200**	**800**	**1,300**	**100%**	**30%**
Grand Total	**4,700**	**6,200**	**1,900**	**2,800**	**4,300**	-	**100%**

Values rounded to increments of 50 MW

COST COMPONENTS

- Exploration
  - Up to drilling first full-diameter well
- Confirmation
  - Drilling until 25% of specified capacity is available at the wellhead
- Development
  - Drilling until 105% of specified capacity is available at the wellhead
  - Surface equipment at $1,500 / kW
  - Transmission-line interconnection

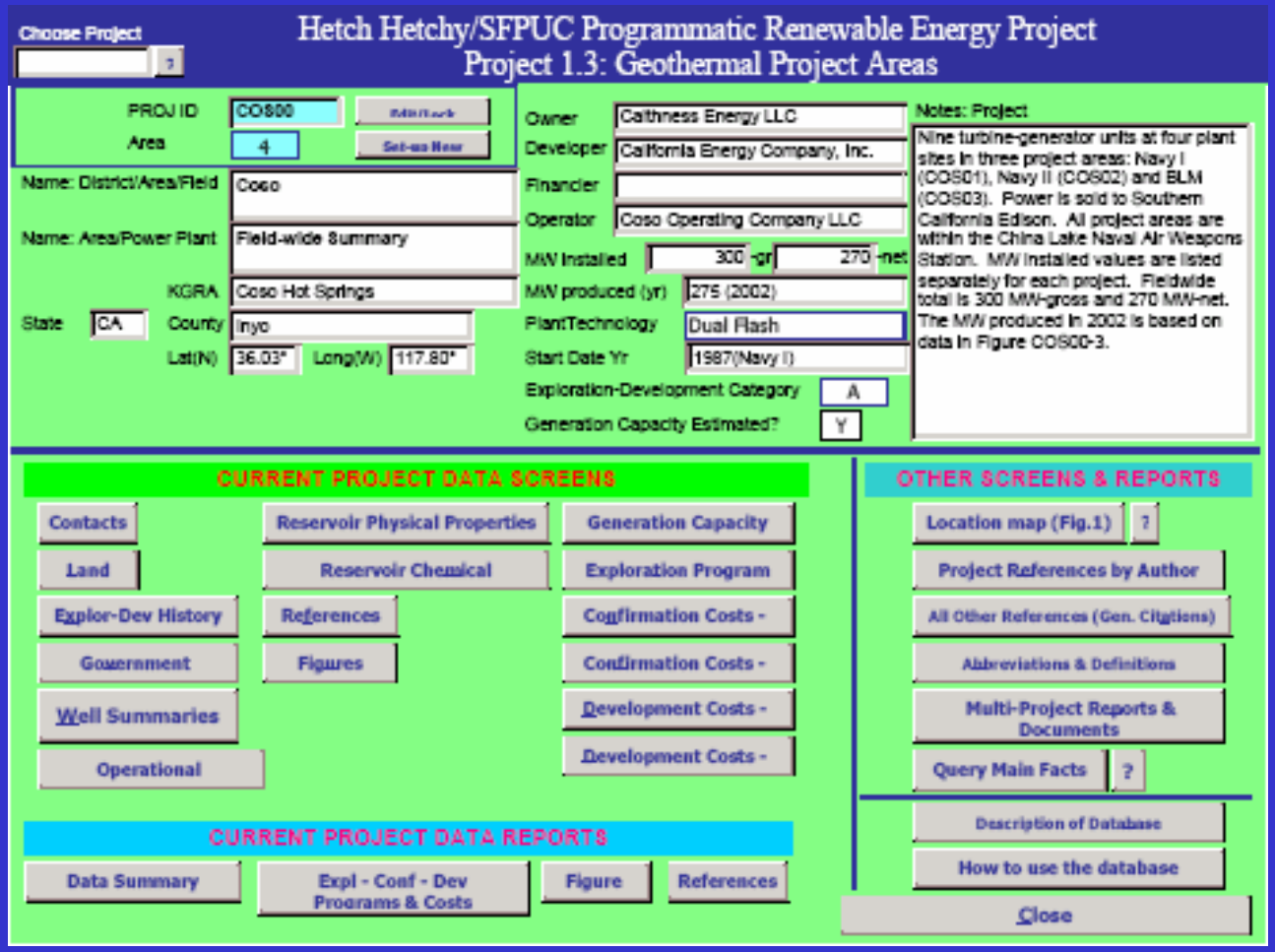
DRILLING COSTS



CAPITAL COSTS

- Overall Average (64 projects): $3,100 / kW
  - Reflects all development costs (including transmission)
  - $2,950 / kW within California
  - $3,400 / kW in Greater Reno and Dixie Corridor
- Incremental geothermal capacity available:
  - 2,500 MW (gross) below average cost of $3,100 / kW
  - 2,000 MW (gross) within California below state average of $2,950 / kW
  - 1,700 MW (gross) below $2,400 / kW (assumed threshold to be competitive with other renewables)
- Subject to further updating once operators and developers have opportunity to comment on report

PIER GEOTHERMAL DATABASE



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How to Get a Copy

- Full report and PIER Geothermal Database are available for free download at:
  - www.geothermex.com
  - On the Home Page, click on CEC-PIER Reports
  - Report is 264 pages (4.2 MB)
  - PIER Geothermal Database is 45.1 MB (zipped)

SUMMARY

- Reserves (Gross MW)
  - Incremental: 4,300 MW
  - Incremental Within California: 3,000 MW
- Costs
  - Average overall: $3,100 / kW
  - Includes estimate of transmission tie-in
- Power Available (Gross MW)
  - Below $2,400 / kW threshold: 1,700 MW

Back-up slides

- The following may be used if time permits or if needed to respond to questions

Exploration – Confirmation Costs

- Geology (field mapping)
- Geochemistry
- Geophysics
  - Gravity
  - Magnetics
  - Resistivity (e.g., TDEM, AMT, CSAMT)
- Intermediate-depth slim holes
- Full-sized confirmation wells (including testing)
  - Success rate 60% for confirmation wells
- Regulatory compliance
- Administration
- Resource assessment report

Development Costs

- Production and injection wells
  - Ratio of injectors to producers depends on technology used (e.g., flash or binary)
  - Success rate 80% for development wells
  - MW per well based on statistical correlation of MW vs. reservoir temperature
- Surface facilities on site: $1,500 / kW
  - Applied for all plant technologies (flash or binary)
- Transmission tie-in estimated in conjunction with separate analysis by another contractor for Hetch Hetchy / SFPUC Project

Exploration-Development History

- Geology, geochemistry, geophysics
- Past drilling
  - Temperature-gradient holes
  - Intermediate-depth slim holes
  - Self-flowing production wells
  - Pumped production wells
  - Injection wells
  - Observation wells
  - Includes completion statistics if available

VOLUMETRIC CAPACITY ESTIMATE

- Reservoir properties
  - Average temperature
  - Depth to top
  - Thickness
  - Area
  - Porosity
- Other factors
  - Recovery factor (0.05 to 0.20)
  - Heat capacity of rock (39 BTU/ft^3 °F)
  - Utilization factor (45%)
  - Capacity factor (90%)
  - Plant life (30 years)